

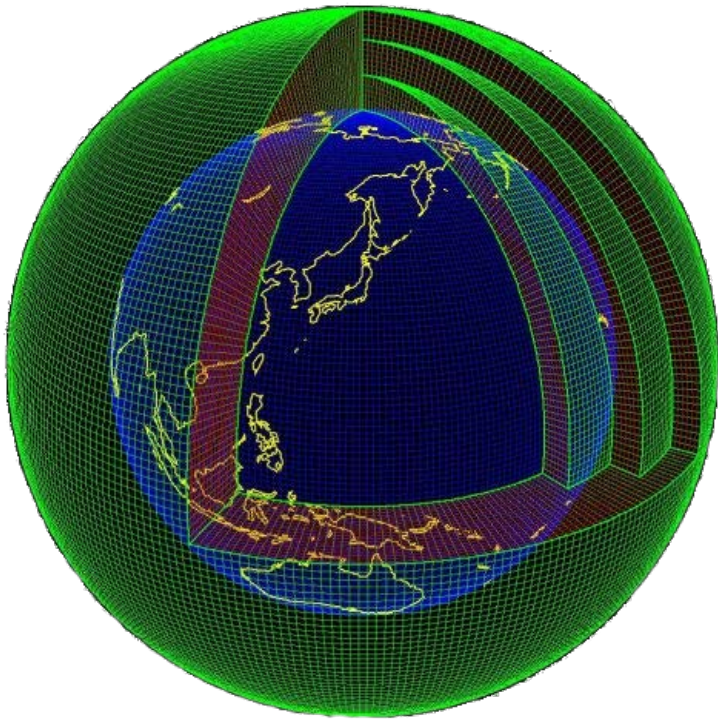
# **Additional Data via Autonomous Systems to Supplement Traditional Sparse Sources for Weather Forecasting and Atmospheric Science**

Dr. Suzanne Weaver Smith, University of Kentucky  
Donald and Gertrude Lester Professor of Mechanical Engineering  
Director, NASA Kentucky Space Grant and EPSCoR Programs  
Director, UK Unmanned Systems Research Consortium

Commonwealth Computational Summit

October 17, 2017

# Predictive Weather Models



<https://public.wmo.int/en/our-mandate/weather>

Foundations in the early 1900s

Supercomputing in the 1970s

Numerical methods for scale interactions,  
boundaries, initialization, time-stepping

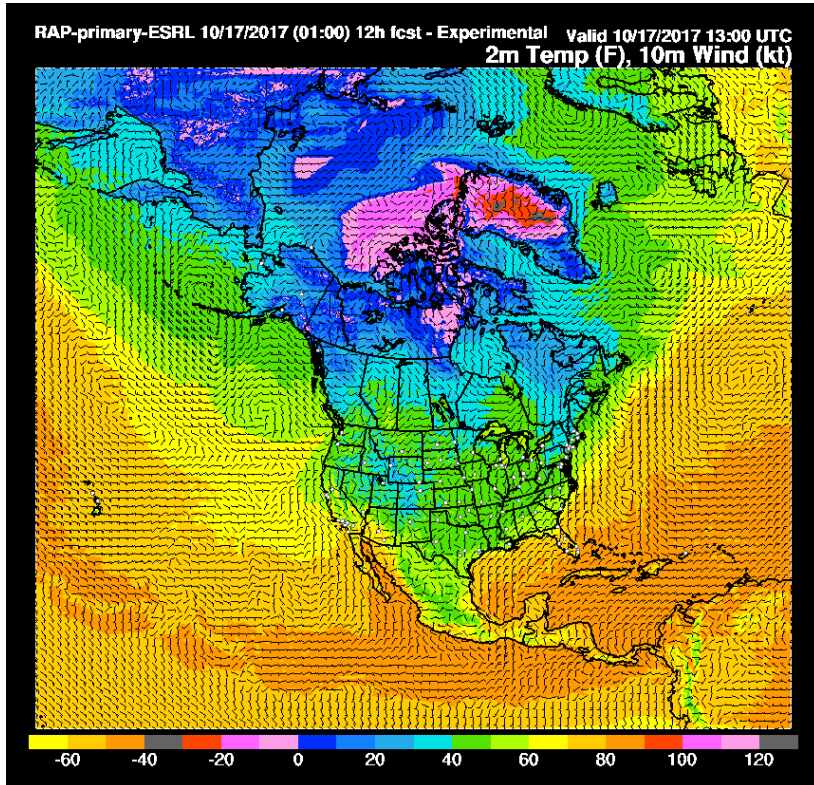
Hierarchy of models and complexity

Physical process representation

Ensemble forecasting

Model initialization

# U.S. Weather Prediction



<https://rapidrefresh.noaa.gov/>

<https://rapidrefresh.noaa.gov/hrrr/>

## Current RAPv3/HRRRv2 Models

Applications (2 to 24-48 hrs)

General forecasting, renewable energy,  
severe storms, and aviation planning

RAPv3 (1 hr update, 13 km grid)

Continental scale assimilation/modeling

HRRRv2 (1 hr update, 3 km grid)

Assimilation of 3 km radar @15 min

Assimilation of RAP 13 km @ 1 hr

Cloud/convection model

Est grid points/surface area:

RAP: 300,000; HRRR: 5,000,000

# Weather Observations and Data

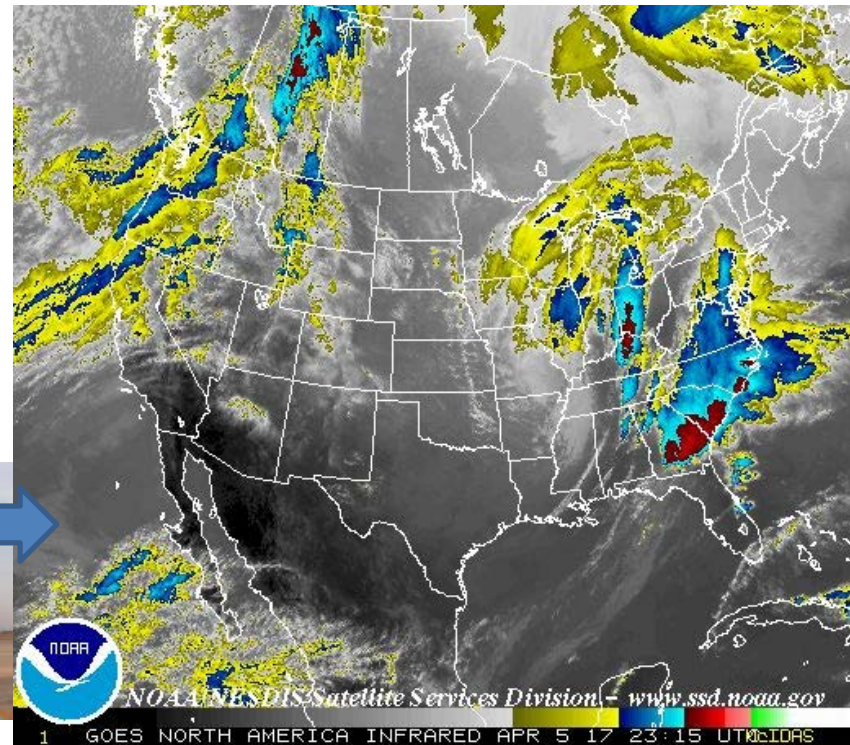
Hourly sources for  
observations



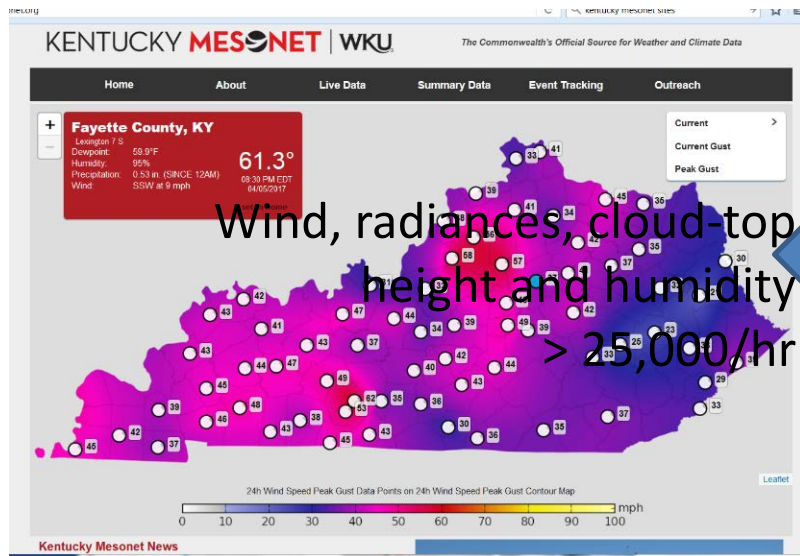


# Weather Observations and Data

Wind, radiances, cloud-top  
height and humidity  
> 25,000/hr

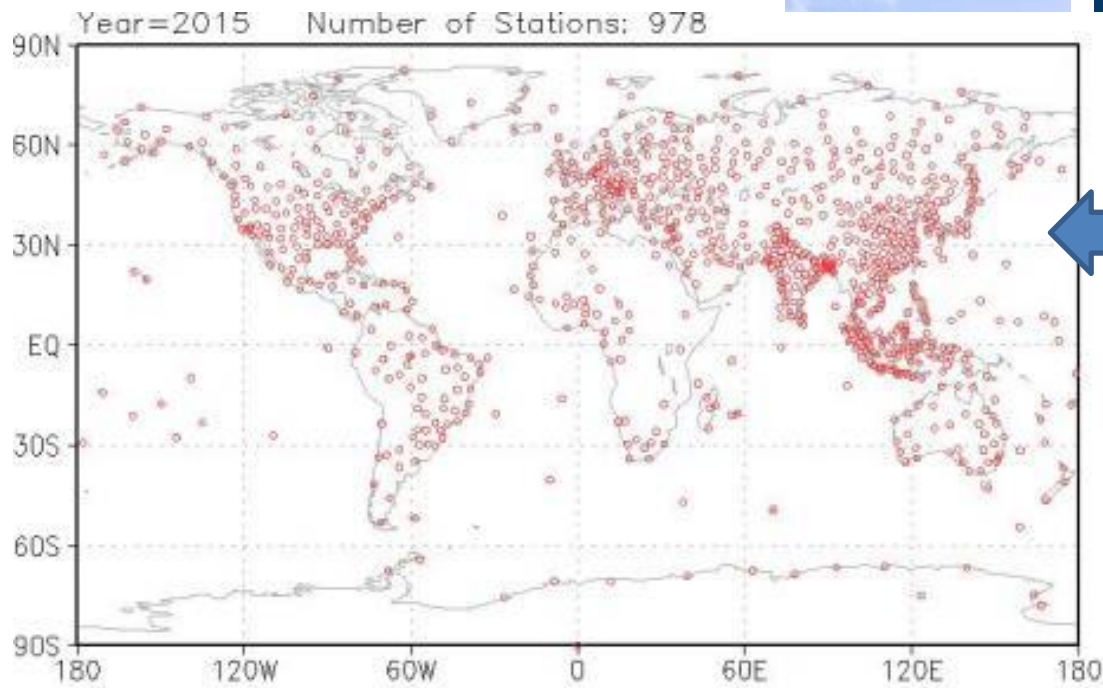


# Weather Observations and Data



Temperature, moisture,  
wind, pressure, clouds,  
visibility, weather  
> 15,000/hr

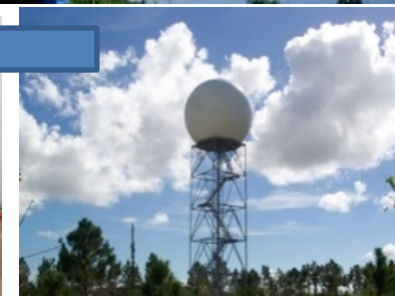
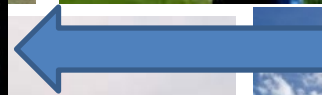
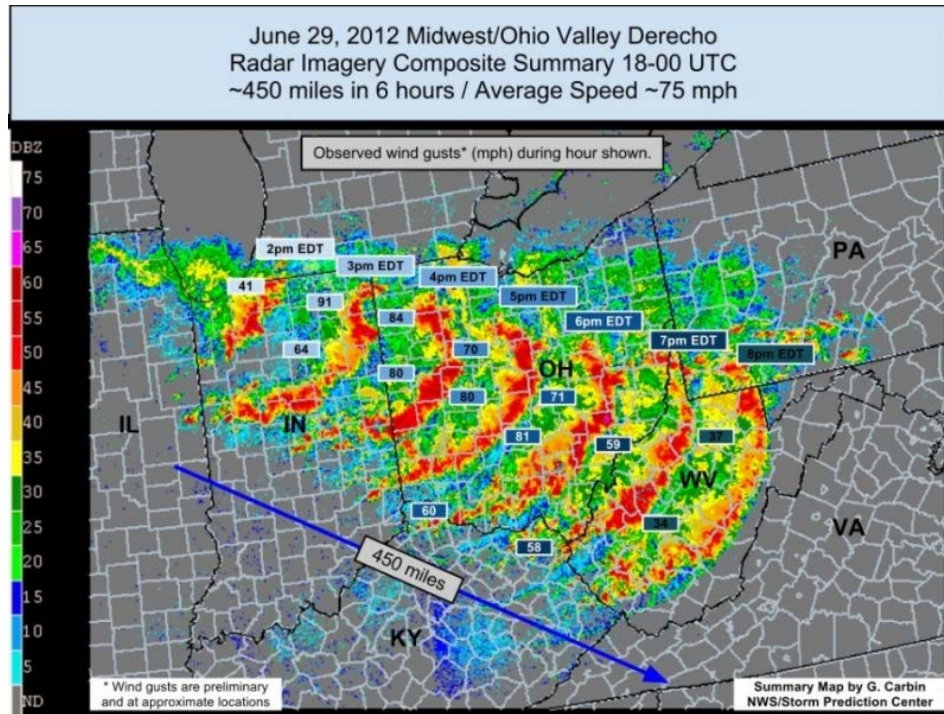
# Weather Observations and Data



Temperature, humidity, wind, pressure  
~ 150/hr



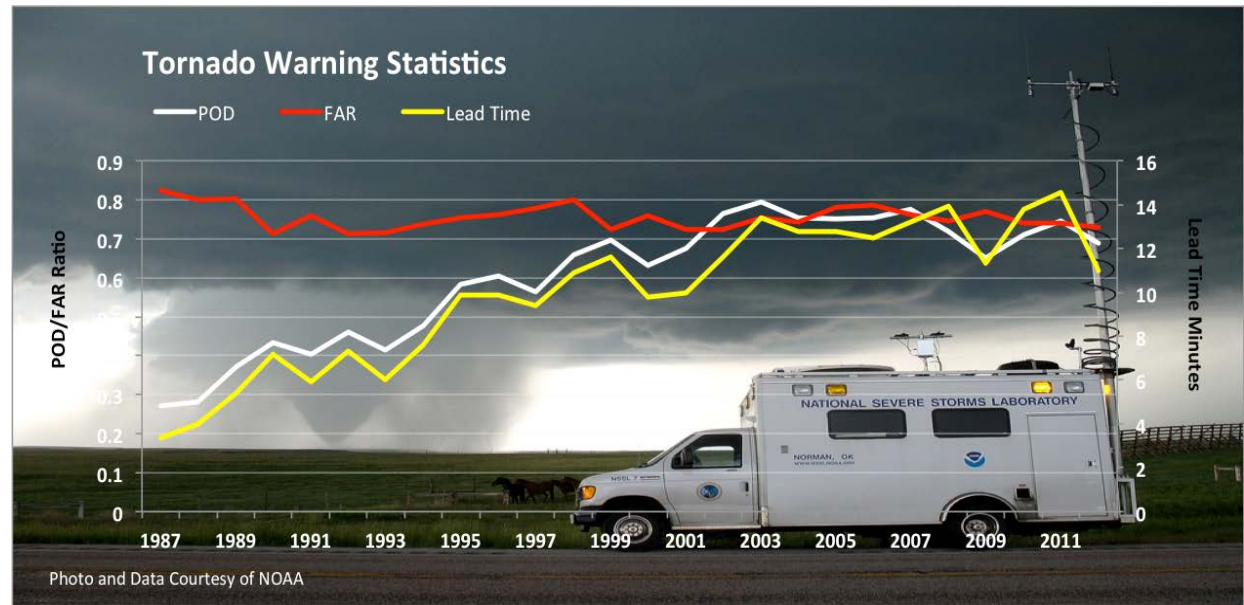
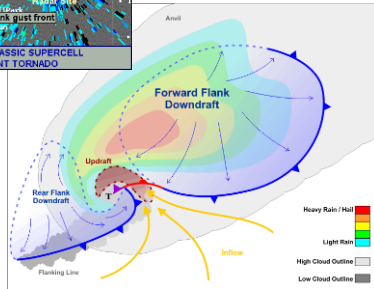
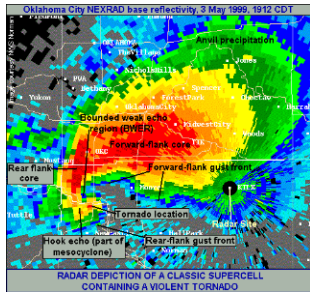
# Weather Observations and Data



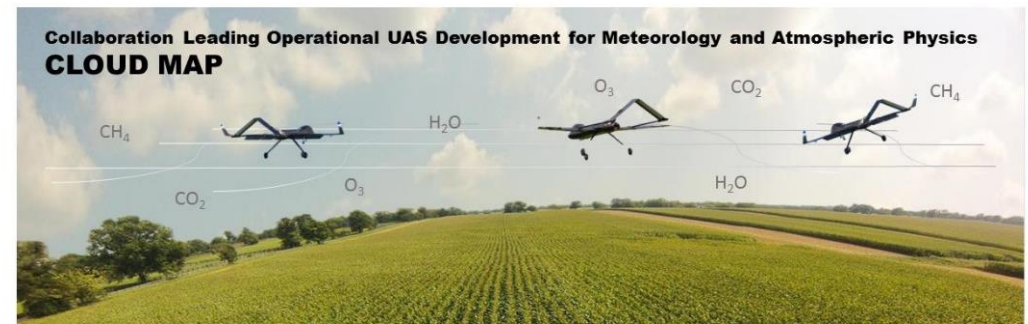
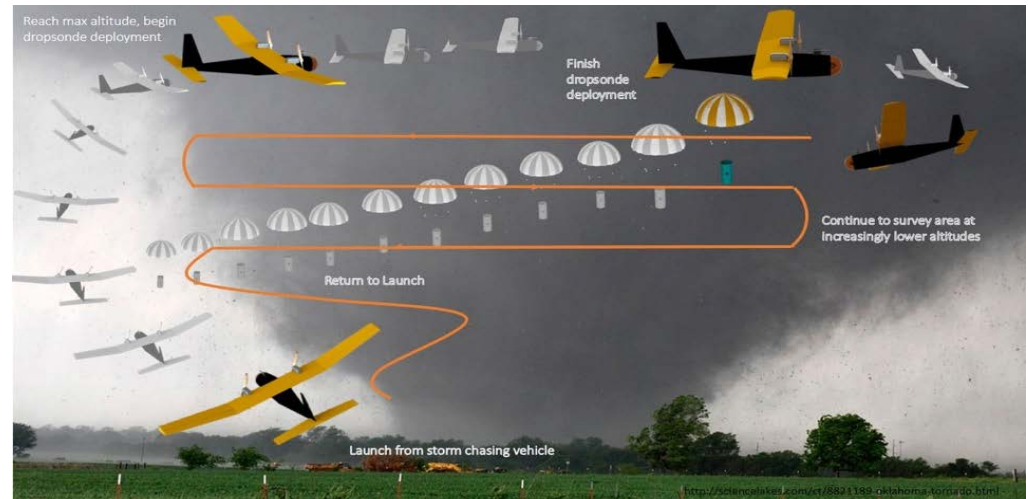
Wind, radial velocity, rain, snow, lightning  
1,500,000/hr, plus 125 radars



# Severe Weather – Anatomy of a Supercell



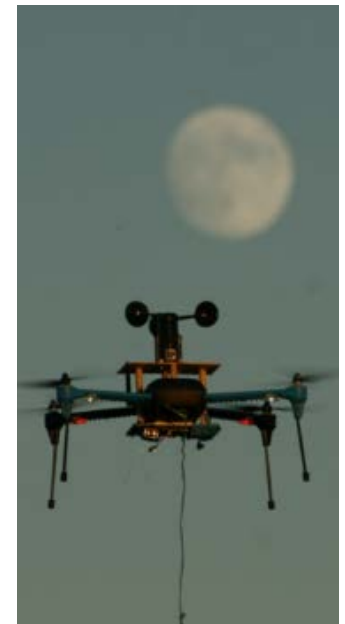
# Research Toward Envisioned Reality



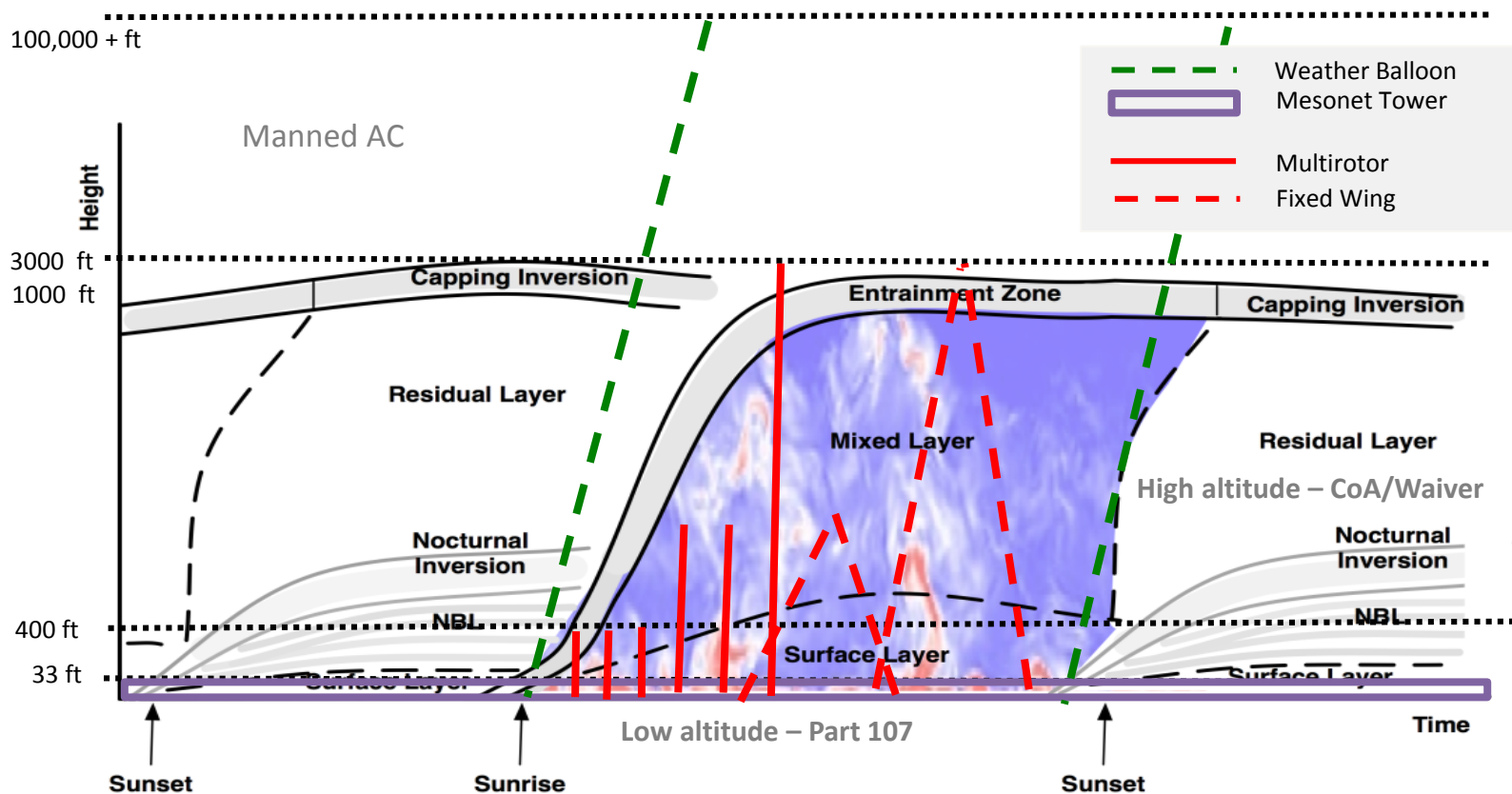
# Drones for Weather Observations

The lowest part of the atmosphere (boundary layer) is directly influenced by terrain, ground use (forest, crops, urban, etc.) and diurnal cycle affecting heat transfer, pollution dispersion and advection, turbulence, and agricultural and urban meteorology.

The Boundary Layer is Accessible  
Using UAS



# Small UAS In Boundary Layer Meteorology

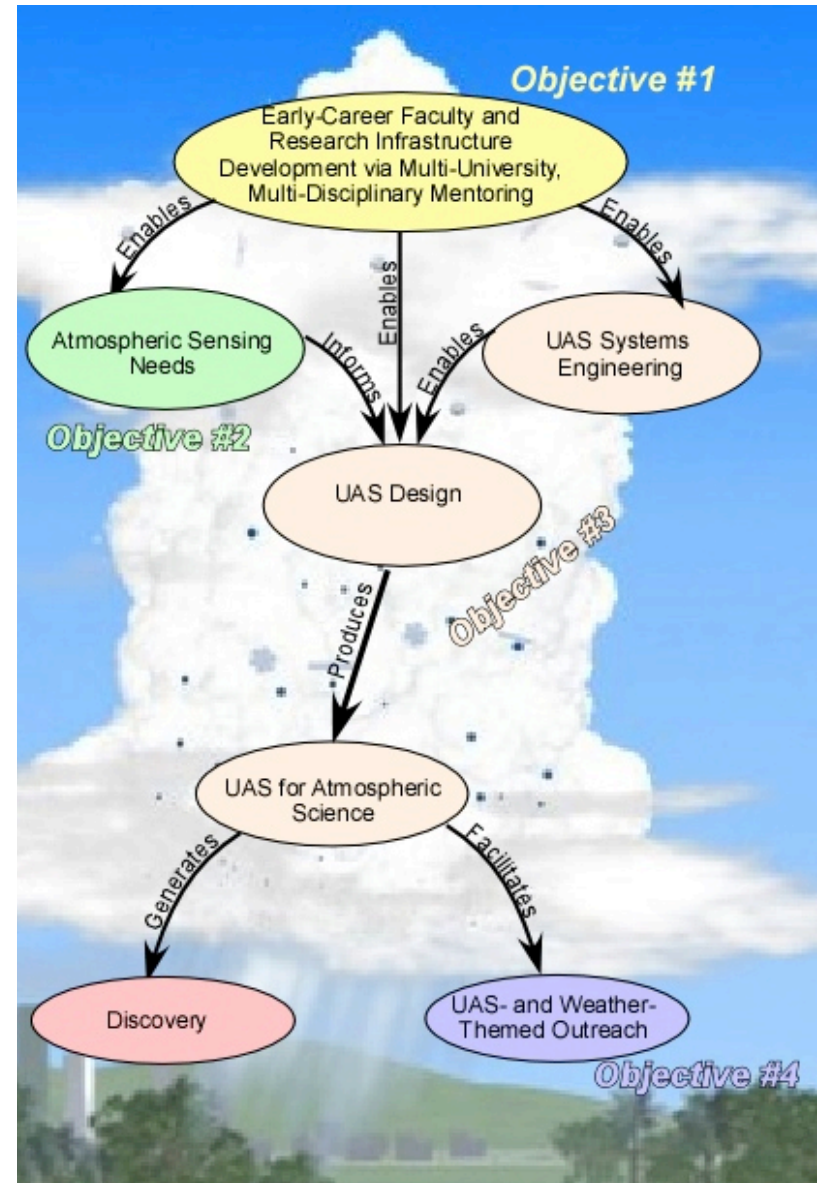




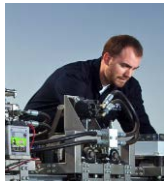
# CLOUD-MAP

Collaboration Leading Operational Uas Development for Meteorology and Atmospheric Physics

1. Develop a strong mentoring program and intellectual center of gravity in the area of *UAS in Weather* and develop joint efforts for the development of a national center in use of UAS in Atmospheric Science.
2. **Create and demonstrate UAS capabilities needed to support UAS operating in the extreme conditions typical in atmospheric sensing, including the sensing, control, planning, asset management, learning, control and communications technologies.**
3. **Develop and demonstrate coordinated control and collaboration between autonomous air vehicles.**
4. Develop and conduct UAS themed outreach in support of NSF's technology education and workforce development.



# CLOUD-MAP Team



Atmospheric Physics

Risk Dissemination

RF Communication

Storm Microphysics

Public Perception

Distributed Data

Convection Init.

Climatology

Hydrology

Chemistry

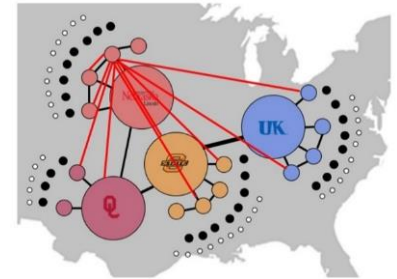
Swarming

Infrasound

Sensors

GIS

**UAS**



*>100 NSF participants  
including  
faculty and trainees  
(even more w/staff)*

# 2017 UK-only Campaign Summary

## Fixed Wing Flights

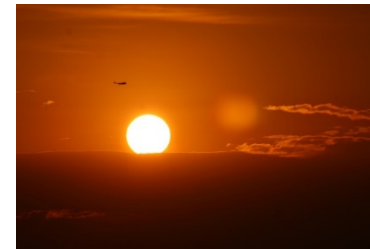
- Skywalker X8's in triples or pairs
  - Turbulence transects or multi-unit control
  - 39 flights, 33.183 hrs

## Rotorcraft Flights

- Solo (Sonic), DJI Phantom (Chem and BAE), S1000+ Octocopter (BAE)
  - Profiling or remote ground sensing
  - BAE: 20 flights, 5.017 hrs
  - Chem: 36 flights, 9.055 hrs
  - ME: 44 flights, 9.733 hrs

**Total: 139 flights; 57 hrs**

**UK to host researchers in  
Kentucky in 2018!**





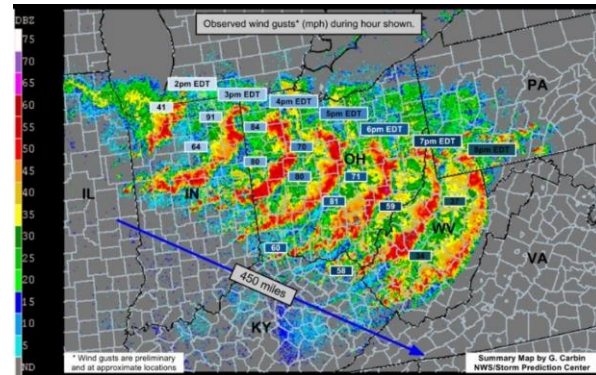




# Drones Can Answer Important Questions

## Science:

- Identify Fuel for Bow Echo (Straight Line) Winds?
- Influence of Cold Pools on Storms and in Valleys?
- Effects of Ground Features?



## Modeling:

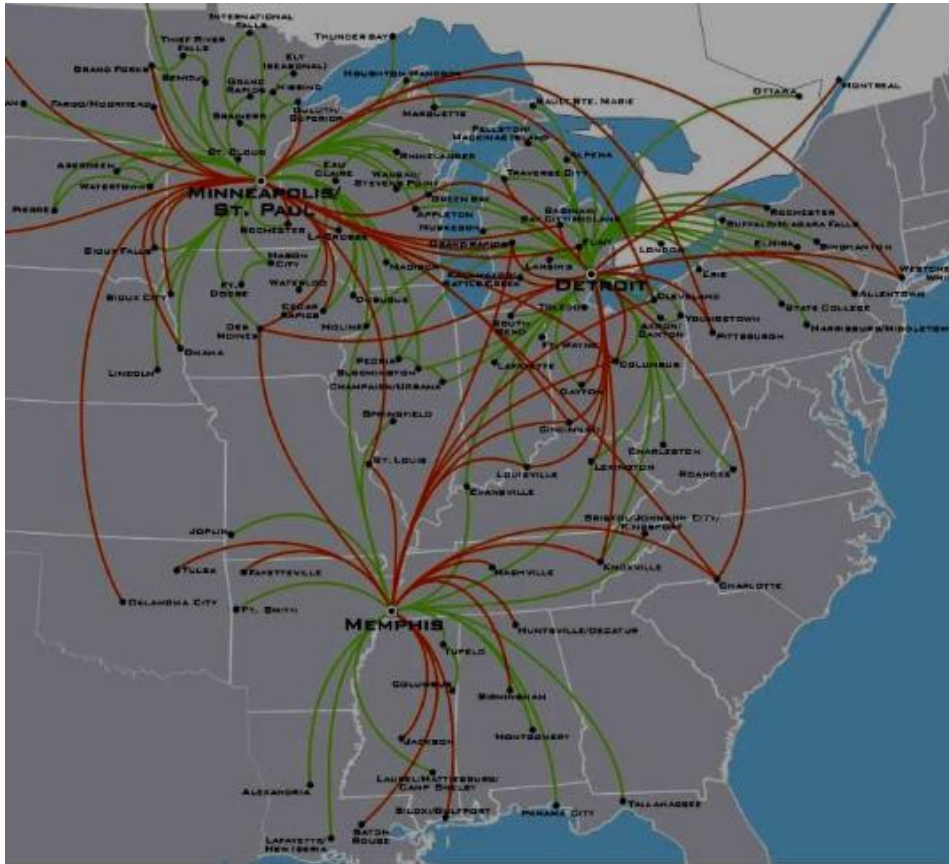
- Validate Physical Process Models

## Observations:

- Assimilation Data



# Flights and Weather



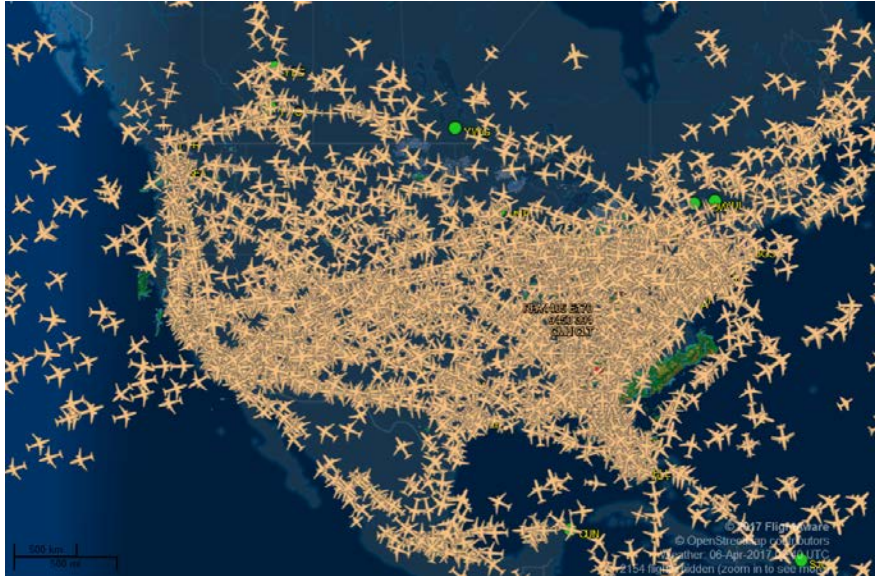
From NASA Evaluation (2006)  
Tamdar Sensor on Commuter  
Flights

Today, TAMCARS sensors on  
>400 aircraft flights daily  
contribute observations to  
AirDat forecasting



<http://www.airdat.com/tamdar/index.php>

# Flights and Weather



Flight Tracker (4/5/17)

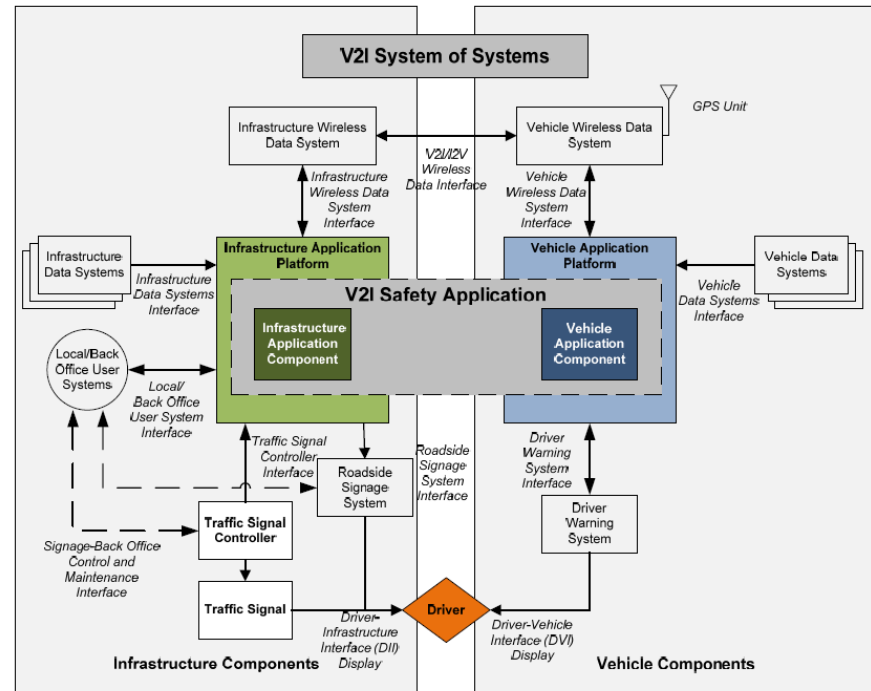
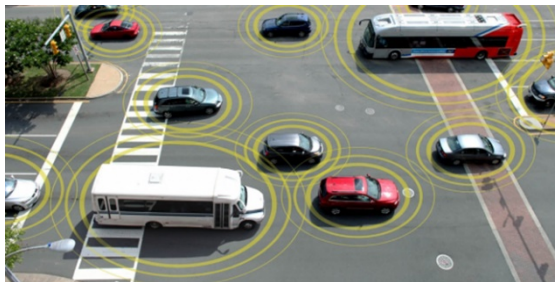


SkyWest Route Map (Oct 2017)

In one year, controllers handle an average of 64 million takeoffs and landings."  
- From the National Air Traffic Controllers Association (<https://www.natca.org/>)

<https://sos.noaa.gov/datasets/air-traffic/>

# Weather and Traffic Management



FHWA-JPO-16-253, "Vehicle-2-Infrastructure (V2I) Safety Applications; Performance Reqts, Vol. 6, Spot Weather Information Warning – Diversion (SWIW-D)," Aug 2015

<https://www.forbes.com/sites/oliviergarret/2017/03/03/10-million-self-driving-cars-will-hit-the-road-by-2020-heres-how-to-profit/#717faf8c7e50>

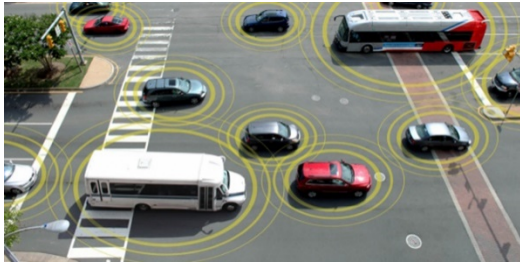
<http://fortune.com/2017/01/06/drones-registrations-soaring-faa/>



# Future Observations including Autonomous Systems

Hourly Observation Type	Variables Observed	Observation Count
Satellites	Wind, radiances, cloud-top height and humidity	>25,000
Ground Stations (Mesonets, etc.)	Temperature, moisture, wind, pressure, clouds, visibility, weather	>15,000
Balloons	Temperature, humidity, wind, pressure	~150
Radars	Wind, radial velocity, rain, snow, lightning	>1.5M, plus 125 radars
Aircraft (TAMDAR, US flights)	Temperature, pressure, winds, humidity, icing, turbulence	400 daily (TAMDAR); >87,000 daily U.S. flights
UAS	Current: Temp, wind, pressure, aerosols humidity, chemistry, weather; Future: TBD	600,000 registered in 2016; 7,000,000 by 2020
Urban Sensors (e.g., Chicago AoT)	Weather, light, pollution	Chicago:50(2016); 500 by 2018 Urban Heat Island data
Autonomous Vehicles	Future: TBD (weather, temp, humidity, and more affecting road conditions)	10,000,000 by 2020
V2I Infrastructure	Future: TBD (temp, humidity, precipitation, etc)	>75,000 km in U.S. Interstate

# Autonomous Systems Weather Observations



Safer Autonomous Systems Operations  
and Improved Weather Forecasting

Future challenges include the following, among others: Numerical methods to incorporate more, possibly lesser quality, observations into models for forecasting and operations, public commitment to provide public services and standards for observation integration, and regional observation sparsity.



**QUESTIONS?**